MM5 Modeling for Upcoming 8-Hour Ozone Activities in Kansas City

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Air Planning and Development
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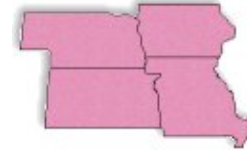901 N. 5th Street
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2002 Study Focus

[1] Modeling project originated in support of CENRAP emissions modeling project (Jan - Jul 2002)

[1] Decided to revisit original MOKAN MM5 simulations for 1995 and 1998 episodes performed by Alpine Geophysics and Environ updated to guage possible performance enhancement for advances in physics and computing capabilities.

[1] Episode(s) selected for future 8-hour photochemical modeling anlayses. Currently being utilized to examine single source impacts with respect to 8-hour ozone designations by Kansas Dept. of Health and Environment and Region 7.

[1] Study also extended to analyze the mesoscale and microscale flow structure over KC Area for more recent episodes (July 2002 - August 2003) to analyze the potential influence of terrain on local flow patterns. Kansas City is bisected by the Kansas and Missouri River Valleys. Working with Dr. Jimmy Adegoke, University of Missouri-Kansas City, for urban flux measurement campaign and comparison with RAMS (August 2003).

[1] FLEXPART Lagrangian Particle Dispersion Model used to analyze 3-dimensional flow structures.

Original MOKAN Meteorological/Photochemical Modeling Study

* Initiated by Kansas, Missouri, and EPA Region VII in 1999 to prepare for transitional 8-hour ozone nonattainment requirements. 3 Episodes selected: June 1995, July 1995, and August 1998.

* 3 Domains Modeled for MM5 Meteorological Model: 108 km, 36 km, 12km

* 24 Vertical Layers for MM5

* Blackadar PBL (June 1995/August 1998) and MRF (July 1995), Kain-Fritsch Cumulus, Simple Ice, 5 layer Soil

* 3 Domains for CAMx Photochemical Model: 36 km, 12 km, 4 km (interpolated from 12 km MM5)

* 10 Vertical Levels for CAMx

Climatological Analysis and Episode Selection

✳ Employing alternative techniques to elucidate climatological conditions favorable for ozone formation in the Kansas City Metropolitan Area.

  – Trajectory clustering analysis utilizing Patterns in Atmospheric Transport History (PATH) developed by Dr. Jennie Moody, University of Virginia

  – Principal Components/Two stage clustering analysis (Dr. Brian Eder, NOAA)

✳ 7 climatological categories identified observed from trajectory cluster anlaysis. Will utilize PCA/Two stage cluster to refine these.

PATH Cluster Results
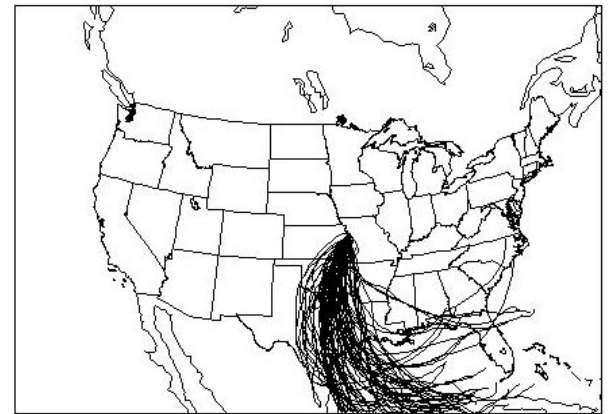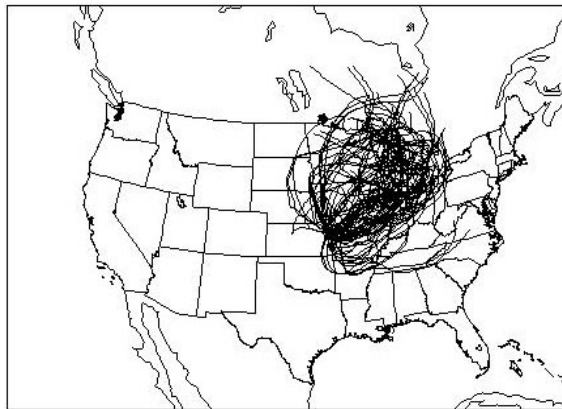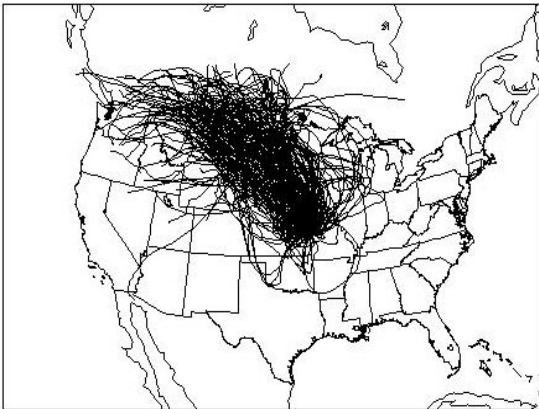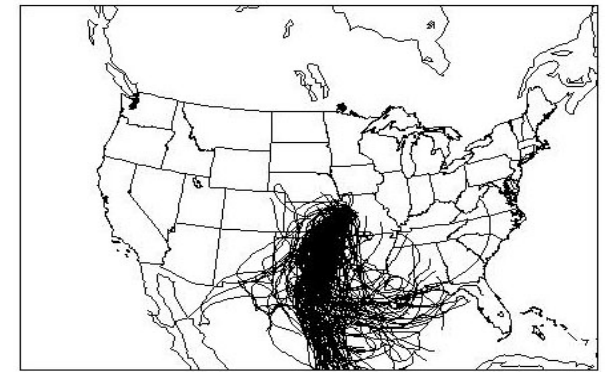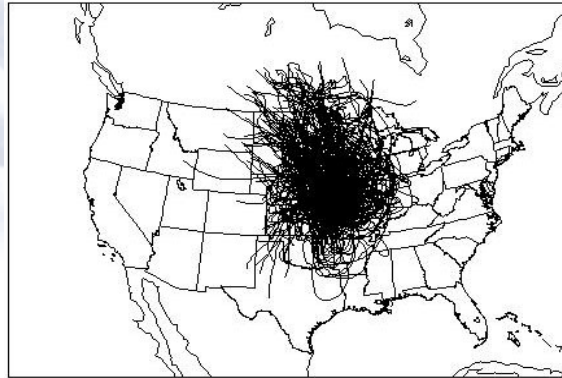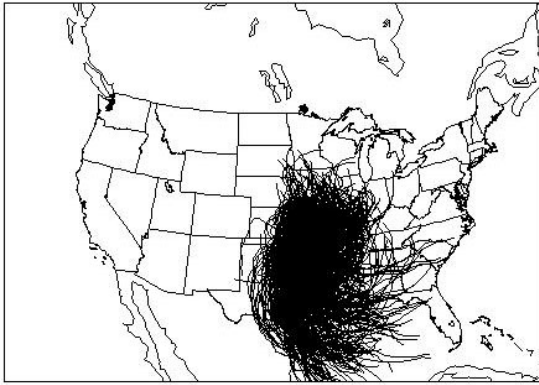
Kansas City Topography

TERRAIN HEIGHT IN COLOR
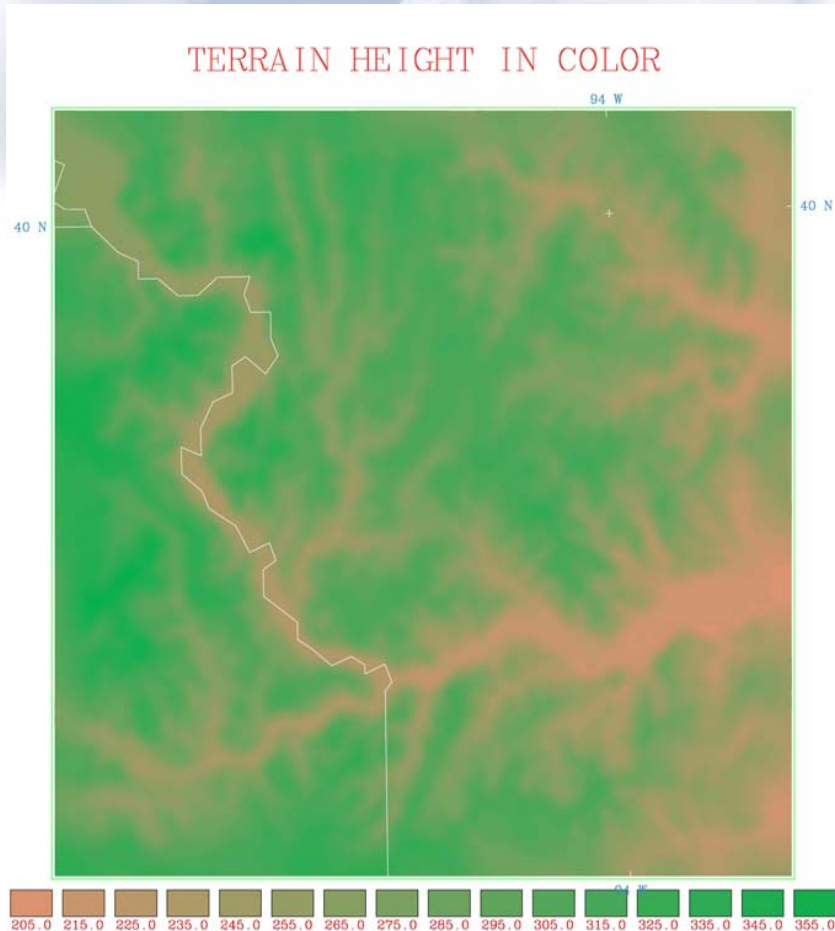
* KC Metro Area bisected by Kansas and Missouri River Valleys.

* Elevation differences range from only tens of meters in some locations to nearly 200 meters along the Missouri River Valley.

MM5 Physics Options

✳ Original configuration:

- Blackadar PBL
- Reisner 2 Moisture
- Kain-Fritsch Cumulus (D1-D2), explicit (D3-D4)
- RRTM Radiation
- Shallow convection
- 5 layer soil
- Analysis nudging D1-D2

✳ Land Surface Experiment

- Pleim-Chang PBL
- Reisner 2 Moisture
- RRTM Radiation
- Kain-Fritsch Cumulus (D1-D2), explicit (D3-D4)
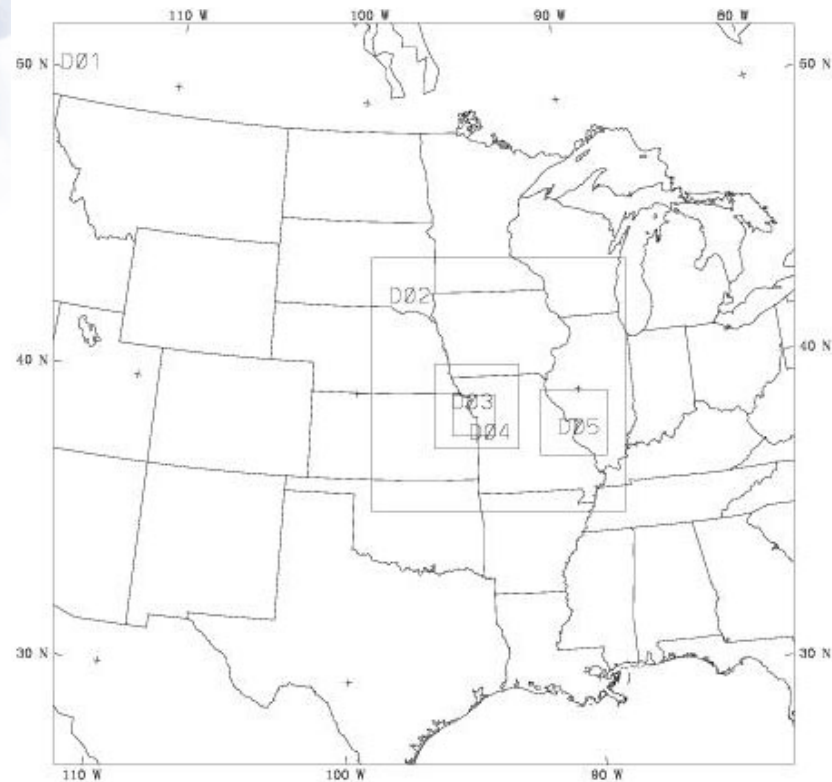- Pleim-Xiu Soil
- Shallow convection

MM5 Grid Configuration

* 4 Domains for Kansas City:

    - 36 km (80 x 80)
    - 12 km (82 x 82)
    - 4 km (52 x 52)
    - 1.33 km (76 x 76)

* Two Way Nesting

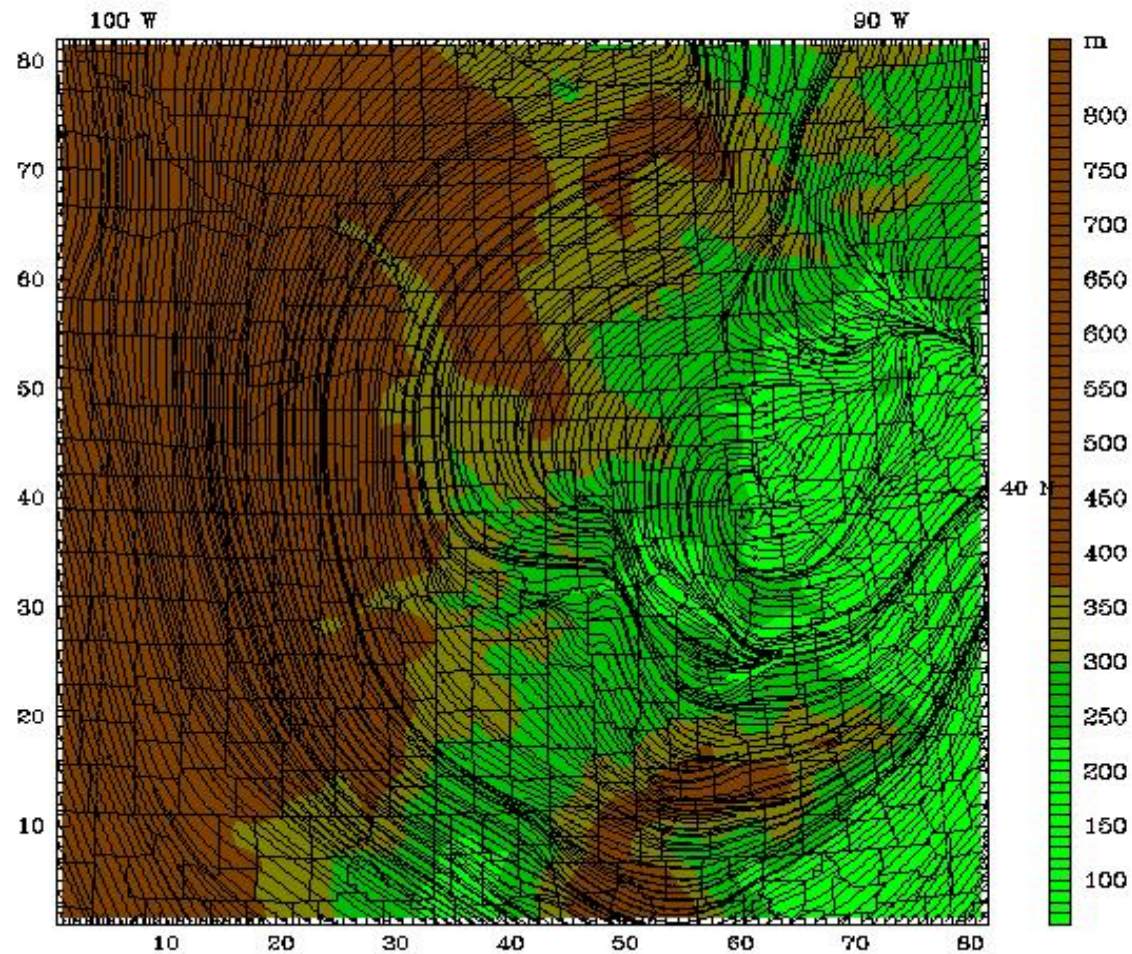* 28-42 Vertical Layers tested

    - Layer structure selected consistent with sensitivities conducted by Dr. Gammons, Texas A&M
    - Requires further examination for KC Area

Domain 2 Winds - 12km

Domain 2 Winds - 12km

Domain 4 Winds - 1.3 km

Dataset: kcma1.3   RIP: rip13   Init: 0000 UTC Fri 05 Jul 02
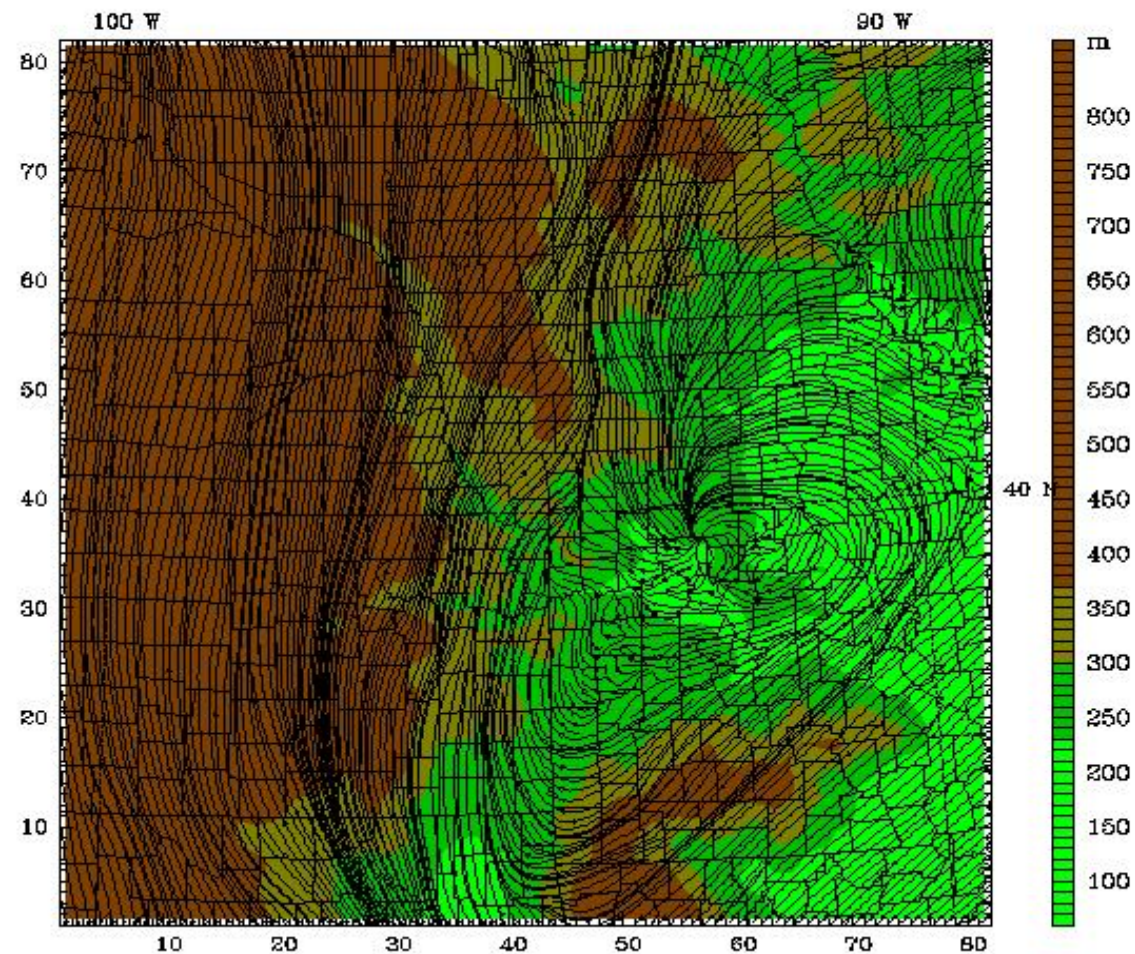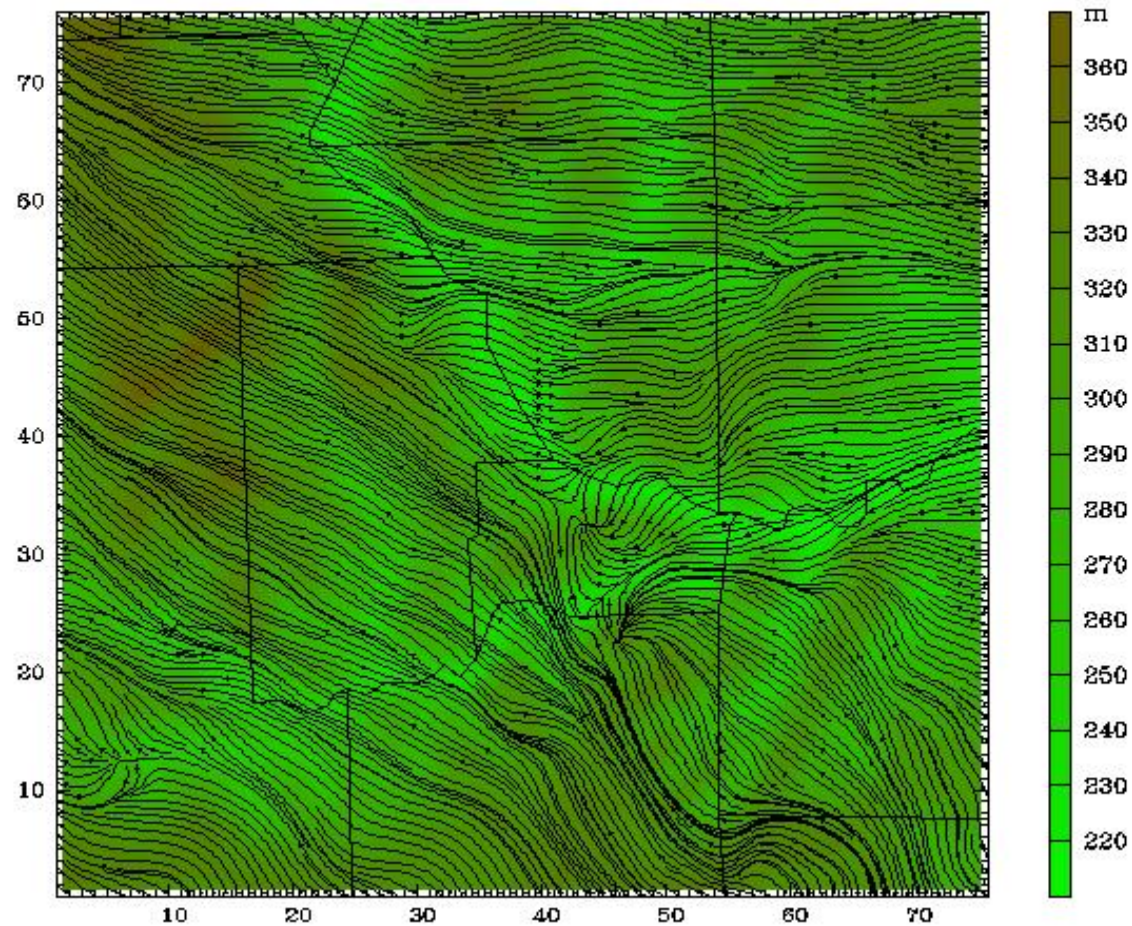Fcst: 41.00   Valid: 1700 UTC Sat 06 Jul 02 (1200 CDT Sat 06 Jul 02)
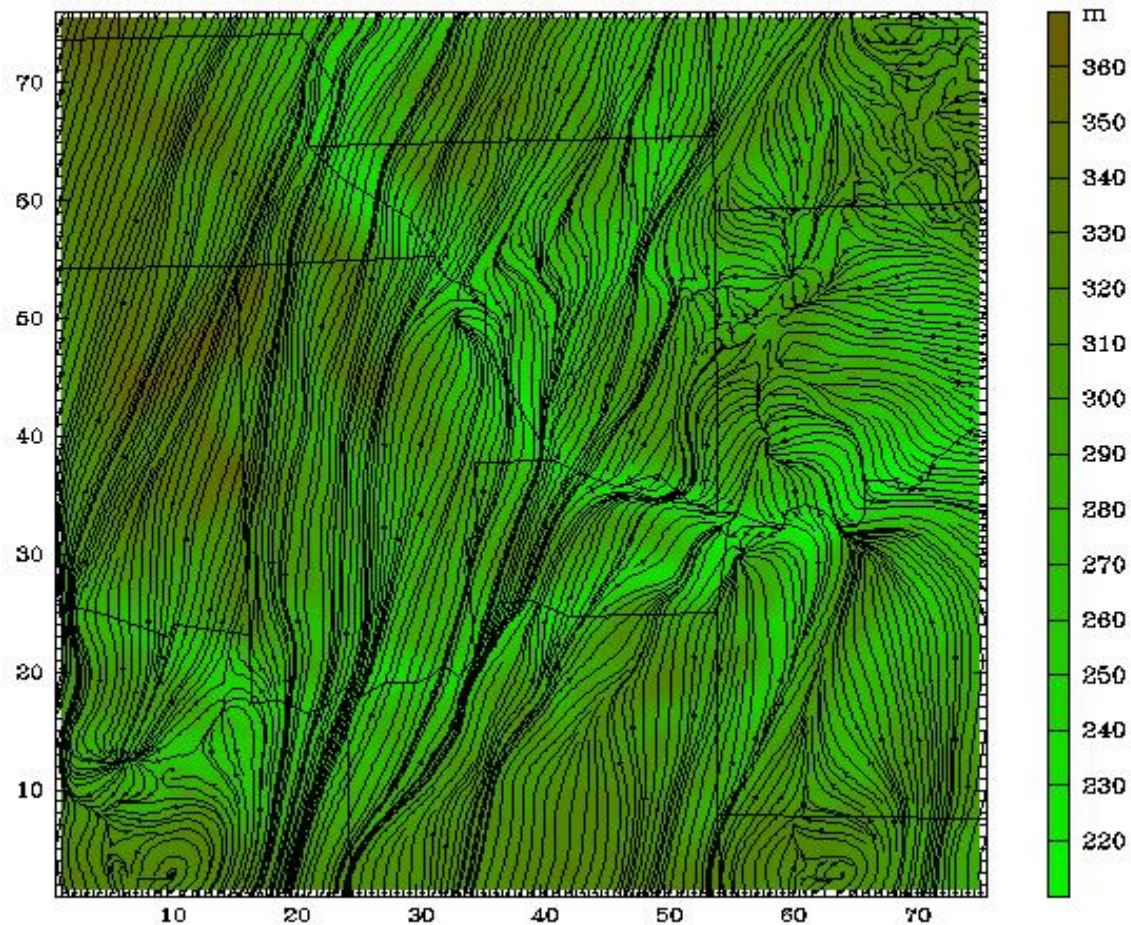Terrain height AMSL
Horizontal wind streamlines   at sigma = 0.995

Domain 4 Winds - 1.3 km

Dataset: kcma1.3 RIP: rip13

Fcst: 65.00

Terrain height AMSL

Horizontal wind streamlines

Init: 0000 UTC Fri 05 Jul 02

Valid: 1700 UTC Sun 07 Jul 02 (1200 CDT Sun 07 Jul 02)

at sigma = 0.995

PBL Evolution

Dataset: kcma1.3   RIP: rip13   Init: 0000 UTC Fri 05 Jul 02
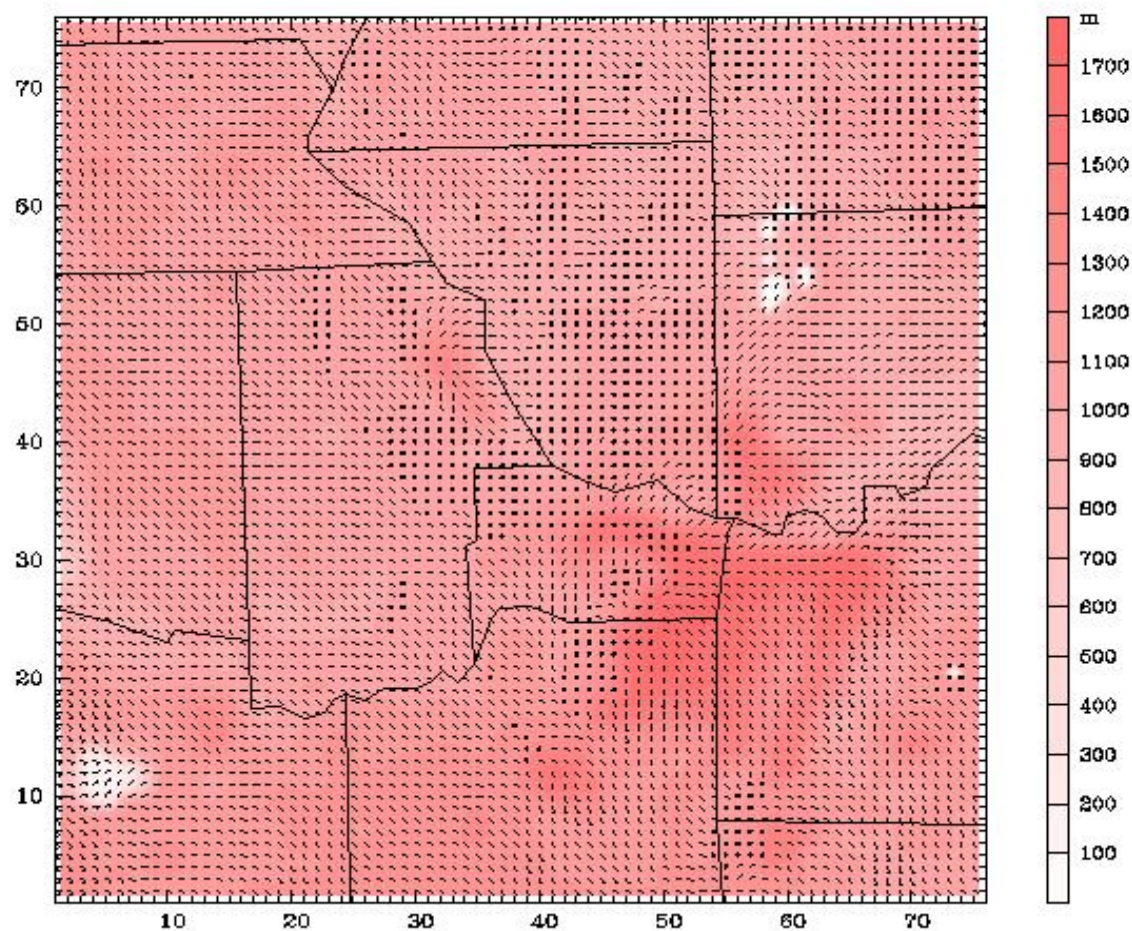Fcst: 40.00   Valid: 1600 UTC Sat 06 Jul 02 (1100 CDT Sat 06 Jul 02)
PBL height
Horizontal wind vectors   at sigma = 0.995

# Model Performance Analysis - Blackadar PBL

* Base case run utilized Blackadar PBL scheme, Kain-Fritsch Cumulus, 5 layer soil model

* Relatively poor performance predicting wind speeds. Does not adequately replicate diurnal wind profile. Phase shift by about 6 hours.

* Consistent overprediction of temperature by 1 - 1.5 degrees K.

* Negative bias on predicted moisture.
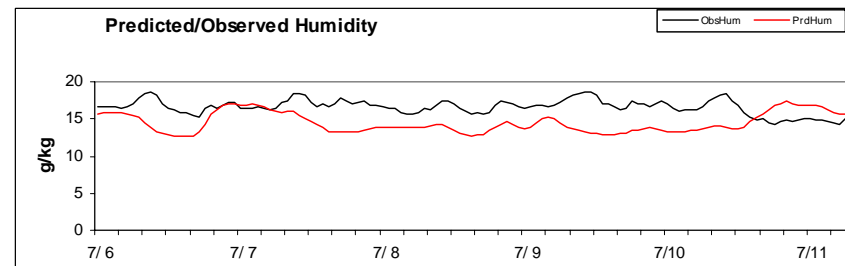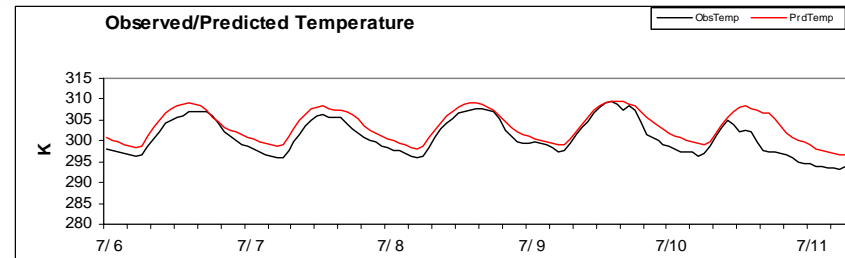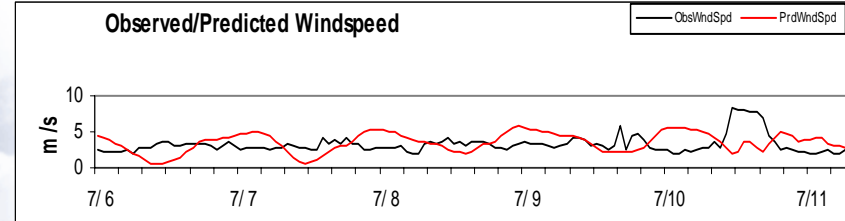
Model Performance Analysis - Pleim-Xu LSM PBL

✳ Base case run utilized Pleim-Xu PBL scheme, Kain-Fritsch Cumulus, Pleim-Chang   soil model

✳ Better performance relative to Blackadar for predicting wind speeds. Still not adequately replicating diurnal wind profile. Phase shift not as pronounced.

✳ Consistent overprediction of temperature by 1 - 1.5 degrees K. Even greater prediction relative to Blackadar.

✳ Negative bias on predicted moisture. Better than Blackadar, but still needs work.
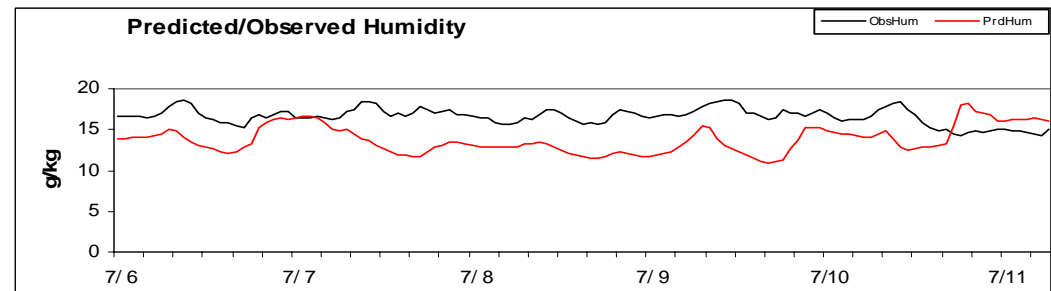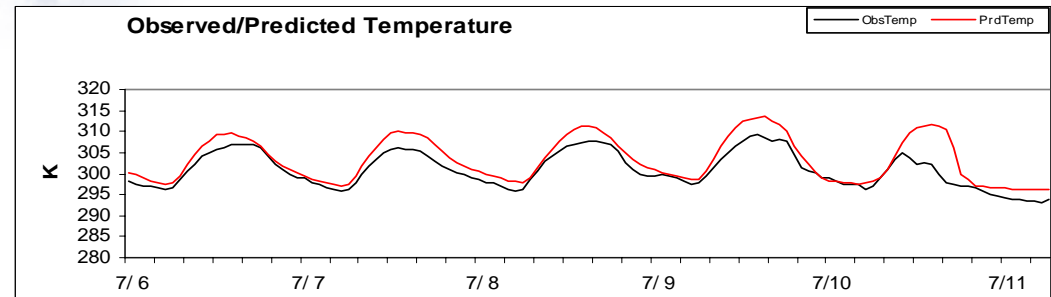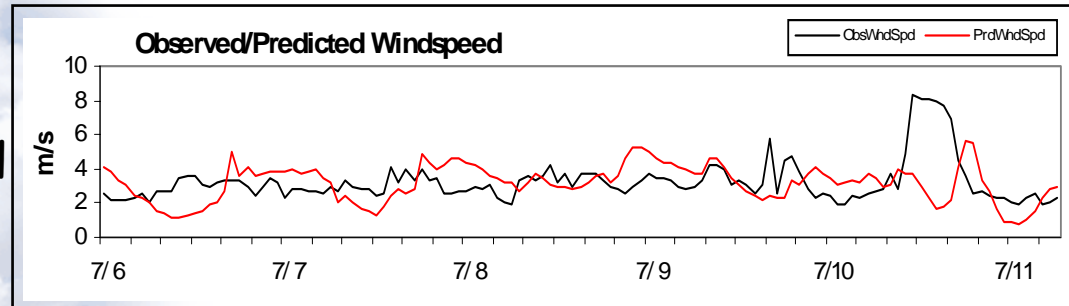
# Flexpart Local Scale Analysis

* Local flow analysis of two simulated sources in KC Area.

* Low level release in Missouri River Valley and Simulation of Kaw Power Station north of EPA building here in KC.

* Low level release representative of small sources and mobile source emissions in metro area.

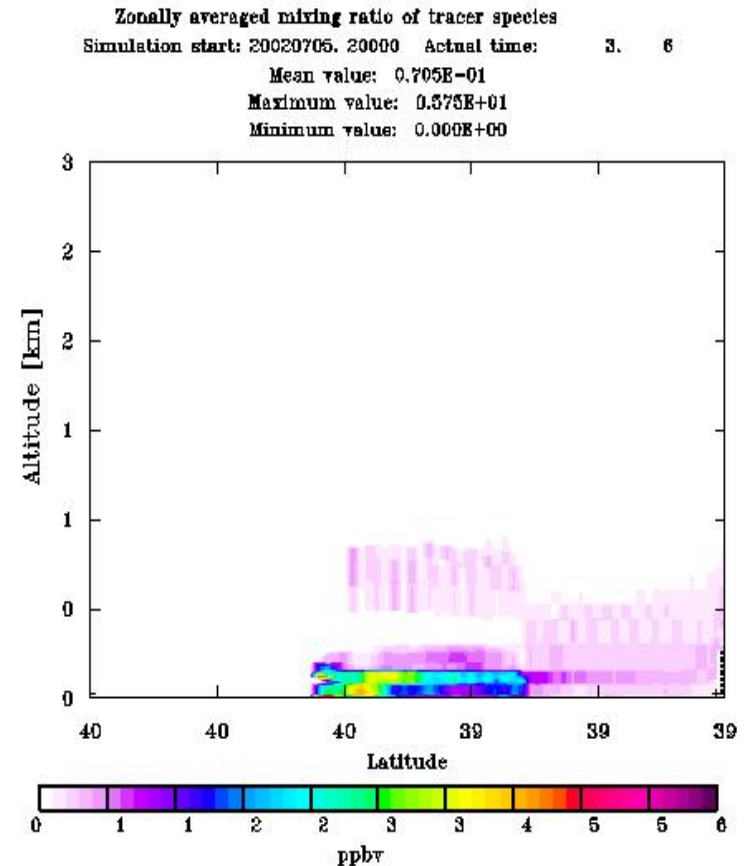* Elevated point source representative of EGU type facilities.

local
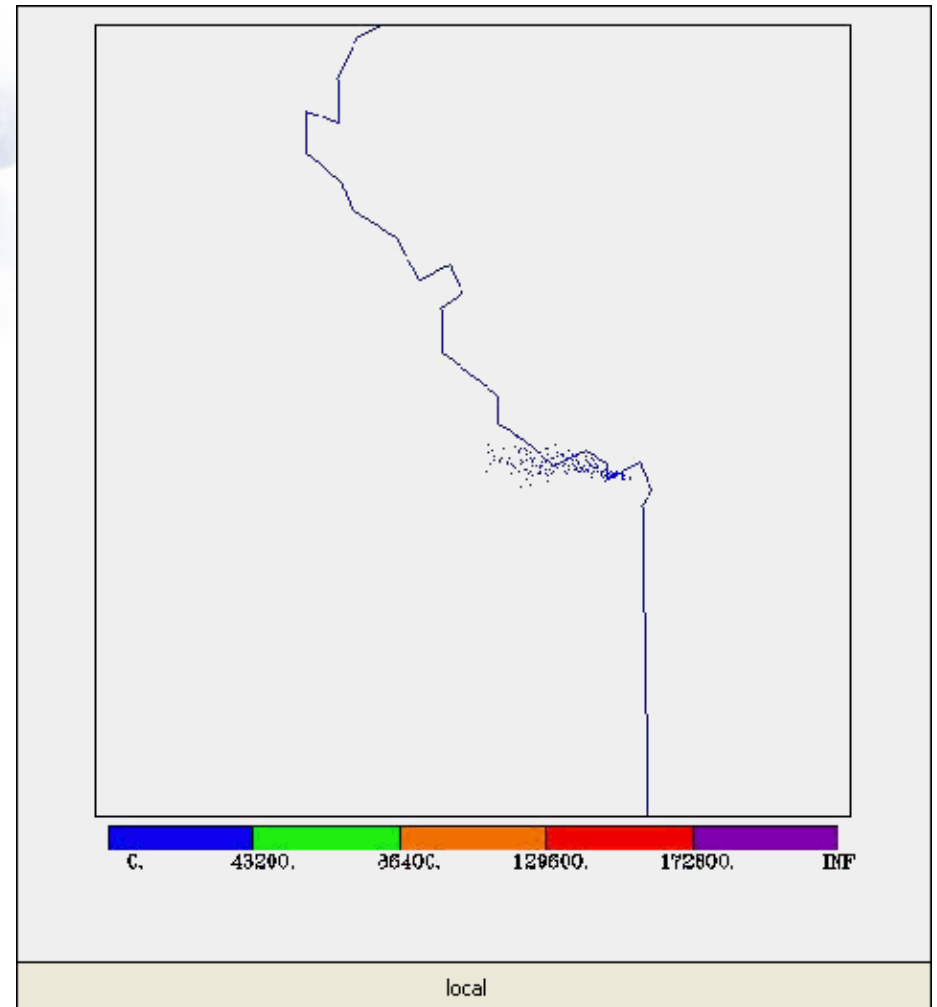
3-D Visualization - OpenDX
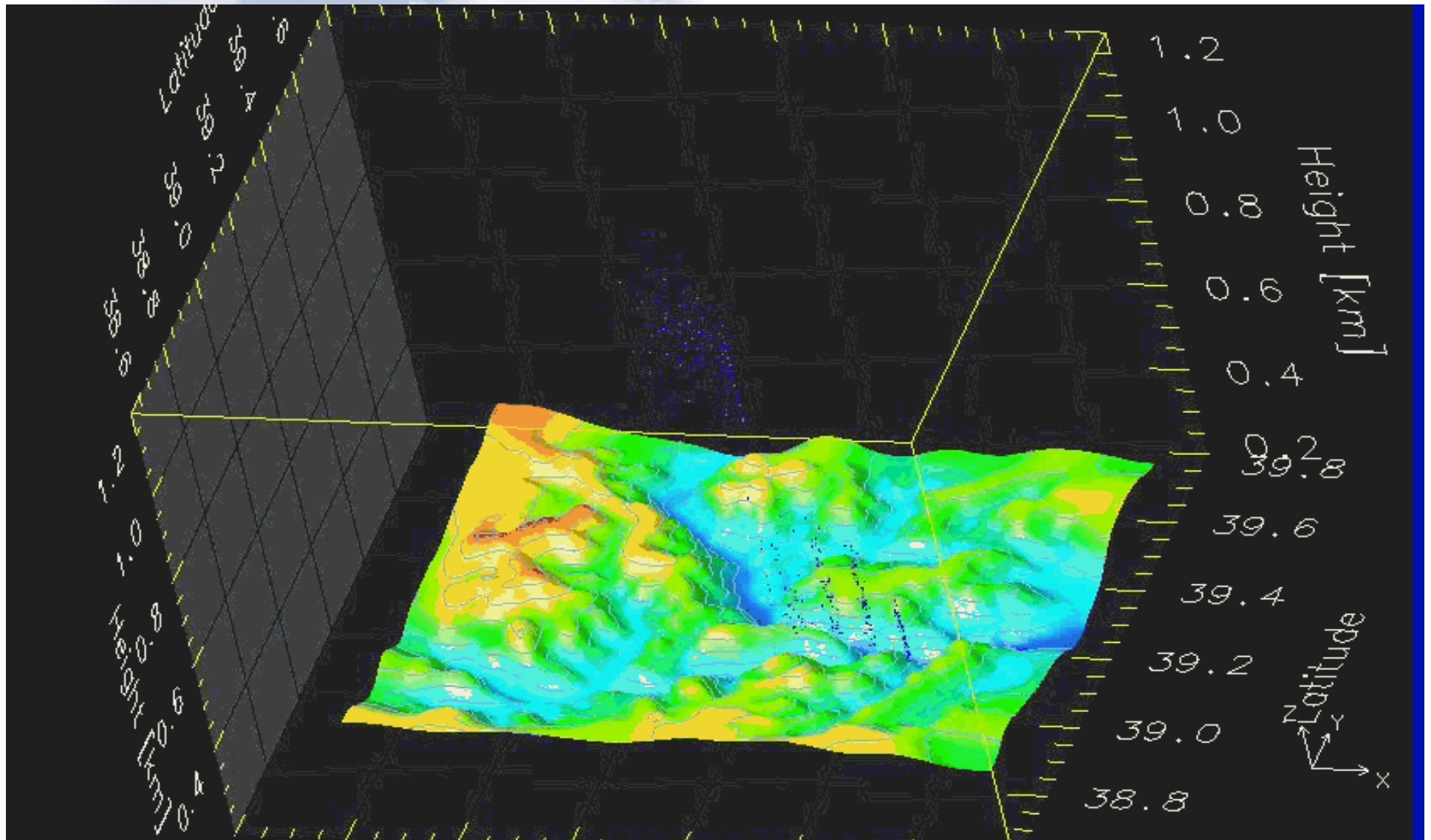
Vertical Cross Section
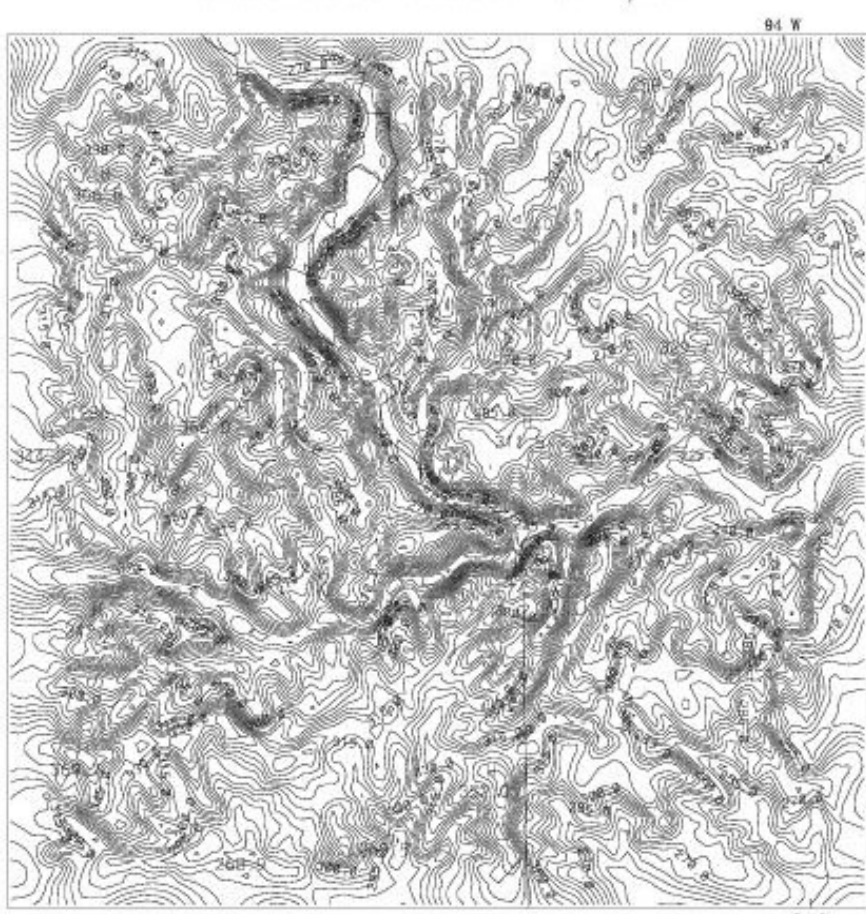
✳ X-Z plane depiction of vertical distribution of hypothetical tracer

    – Narrowly defined gradient at the surface appears to confirm the separation of flow from river valley base to valley top.

Zonally averaged mixing ratio of tracer species
Simulation start: 20020705. 20000   Actual time: 3.   6
Mean value: 0.705E-01
Maximum value: 0.375E+01
Minimum value: 0.000E+00

Topographic Influences?

Ground Level Concentration
Start of simulation: 20020705, 20000   Actual time: 154 h

TERRAIN HEIGHT IN B/W
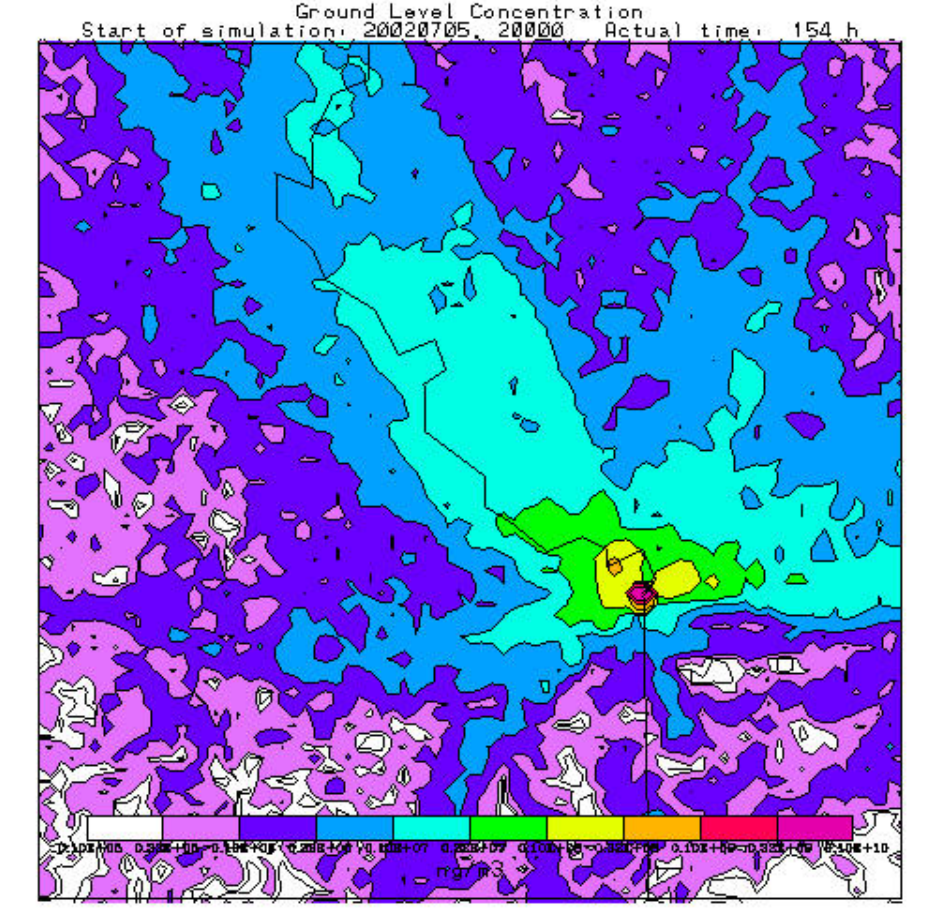
Lessons Learned

1. Previous MM5 simulations appear not to resolve some of the horizontal and vertical flow features observed here in the KC area. MM5/Flexpart simulations show a complex flow structure that needs to be further analyzed to improve performance of photochemical modeling simulations.

1. Terrain channeling of low level sources observed during low wind speed/stagnation conditions. Not resolved at 12km resolution from previous analysis. Need to consider modeling at 4 km or 1.33 km over metro area.

1. Decoupled flows within first 500 meters of atmosphere observed. Previous sensitivity analyses at 28 - 30 layers did not pick up this up well. 40-45 vertical layers appear to pick up the vertical flow feature.

1. Preliminary precipitation analysis indicates K-F supressing convective activity in comparison to Grell.